NNL12AA06C

Traffic Aware Strategic Aircrew Requests (TASAR)

Annualized TASAR Benefits for Virgin America Operations

NASA Technical Monitor:

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September 30, 2014

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Preface

This document describes a simulation study to estimate annualized Traffic Aware Strategic Aircrew Requests (TASAR) benefits for Virgin America operations. This document represents deliverable 41B for TASAR Analysis and Development.

This document was prepared by Engility Corporation, 900 Technology Park Dr., Billerica, MA under Contract No. NNL12AA06C with NASA Langley Research Center, Hampton, VA.

Abstract

The Traffic Aware Strategic Aircrew Request (TASAR) concept offers onboard automation for the purpose of advising the pilot of traffic compatible trajectory changes that would be beneficial to the flight. A fast-time simulation study was conducted to assess the benefits of TASAR to Virgin America. The simulation compares historical trajectories without TASAR to trajectories developed with TASAR and evaluated by controllers against their objectives. It was estimated that about 25,000 gallons of fuel and about 2,500 minutes could be saved annually per aircraft. These savings were applied fleet-wide to produce an estimated annual cost savings to Virgin America in excess of $5 million due to fuel, maintenance, and depreciation cost savings. Switching to a more wind-optimal trajectory was found to be the use case that generated the highest benefits out of the three TASAR use cases analyzed. Virgin America TASAR requests peaked at two to four requests per hour per sector in high-altitude Oakland and Salt Lake City center sectors east of San Francisco.

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1. Introduction

The Traffic Aware Strategic Aircrew Request (TASAR) concept offers onboard automation for the purpose of advising the pilot of traffic compatible trajectory changes that would be beneficial to the flight. The TASAR onboard automation leverages surveillance information to increase the likelihood of air traffic control (ATC) approval of pilot-initiated trajectory change requests, thereby increasing the portion of the flight flown on or near a desired business trajectory. All automation and pilot procedures are fully dedicated to a single aircraft which allows tailoring of optimization criteria to the objectives of each flight and provides for timely responses to changing situations.

A preliminary fast-time simulation benefits assessment[1] estimated the benefits of three TASAR use cases: (1) lateral change after a reroute traffic management initiative (TMI) ends, (2) lateral change in the presence of convective weather, and (3) switch to a more wind-optimal trajectory (altitude, lateral, or combination). The agent-based simulation contained aircrew/TASAR agents that generate requests that improve on the efficiency of historical trajectories and controller agents that evaluate these TASAR requests against their objectives. The benefits of TASAR were assessed for generic network, low cost, regional, and business jet airspace users. Network carriers saved, on average, 543 lbs of fuel (about 80 gallons) per flight and about 3.6 minutes per flight. The rate of Automatic Dependent Surveillance-Broadcast (ADS-B) Out equipage among traffic aircraft did not significantly impact benefits but lower levels of ADS-B Out adoption caused controllers to receive more TASAR requests that may cause conflicts and therefore would not be immediately approveable.

This report builds on the preliminary benefits assessment by tailoring results to a specific airspace user, Virgin America. It extends the previous study by developing estimates of annual fuel and time cost savings due to TASAR tailored specifically for Virgin America. Historical Virgin America trajectories are used as a baseline for comparison to simulated trajectories that consider potential TASAR requests. Also, peak requests by sector are studied in an attempt to further understand the impact of TASAR on ATC.

The document is divided into the following sections:

- Section 1 introduces the annualized benefits assessment
- Section 2 describes three use cases that were quantified
- Section 3 describes the simulation platform and method to quantify benefits
- Section 4 estimates annualized benefits results for Virgin America
- Section 5 estimates impact of TASAR requests on ATC
- Section 6 describes potential future refinements of the benefits assessment

2. TASAR Use Cases Analyzed

Benefits of three types of aircrew requests were quantified. Other types of aircrew requests that were not modeled have opportunities for benefits and therefore this analysis represents only part of the expected full benefit of TASAR. The benefits of the following three types of aircrew requests were quantified in this paper:

1) An aircraft is part of a reroute initiative to avoid convective weather or mitigate congestion. Aircraft in these initiatives are sometimes not shifted back to user-preferred routes after the initiative has ended. The aircrew requests a lateral trajectory change to a more efficient route.

2) An aircraft is impacted by convective weather, and there is sufficient lead time to the convective weather to allow a strategic route change rather than a tactical heading change. The aircrew requests a lateral trajectory change consisting of one or two named waypoints along the trajectory before reconnecting to the route.

3) The aircrew requests a trajectory change (lateral, altitude, or combination lateral and altitude) to switch to a more wind-optimal trajectory. This request for a more wind-optimal trajectory is intended to occur when the aircraft is not impacted by a reroute initiative or convective weather.

The following logic is used to classify flights into one of the three request types. If an aircraft is part of a reroute initiative that began before the aircraft departed, and the reroute initiative is cancelled or ended before the aircraft reached the arrival fix, then the aircraft is classified as aircrew request type (1) above (even if convective weather is present, since there may be overlap between the three request types). The data source for reroute initiatives is the National Traffic Management Log (NTML), available on the Federal Aviation Administration (FAA) Command Center website (www.fly.faa.gov). If at least one of the alternative routes of the aircraft is projected to enter convective weather, and the aircraft is not part of a reroute initiative that ends or is cancelled, then the aircraft is classified as request type (2). The data source for convective weather is Next-Generation Radar (NEXRAD) radar mosaic base reflectivity (www.ncdc.noaa.gov). Certain conditions allow aircraft to request a higher altitude to fly over convective weather, but this is not included as part of (2) and so convective weather tops data is not considered. All other aircraft are classified as request type (3). However, there is overlap between the aircrew request types since the aircrew seeks a wind-optimal solution in all cases, but aircrew request type (3) does not have a reroute initiative or severe convective weather impacting the aircraft.

3. Simulation Platform and Method to Quantify Benefits

An existing fast-time simulation platform that connects to the Future Air Traffic Management Concept Evaluation Tool (FACET) through an Application Programming Interface (API) was used to model trajectories and airspace structure such as routes and sectors. In the integrated platform, two instances of FACET were used. One instance of FACET, the simulator FACET, was used to model the current state (simulation clock

time) of aircraft trajectories. The other instance of FACET, the predictor FACET, was used to model future states of aircraft trajectories to test TASAR aircrew requests for conflicts with surrounding aircraft, conflicts with airspace hazards, and to calculate the impacts of TASAR aircrew trajectory change requests on user time and fuel objectives. Both the simulator and predictor instances of FACET were updated at one minute increments.

Input files to the simulation platform contain flight plans as well as corresponding historically flown four-dimensional (4D) trajectories. Aircraft were modeled to follow their flown trajectory until an aircrew request is granted. Traffic information was obtained from historical Aircraft Situation Display to Industry (ASDI) data.

FACET was configured to predict future aircraft positions differently for historically flown 4D trajectories as compared to alternate trajectories generated by TASAR. Aircraft following their historically flown 4D trajectory did not use aircraft performance or atmospheric models and instead, arrived at the 4D waypoints as specified in the input file. For synthesizing alternate trajectories generated by TASAR, FACET converted the flight plan to a series of latitude and longitude waypoints that were simulated based on aircraft performance models. Wind modeling was based on historical Rapid Update Cycle (RUC) winds data that was read from outside of FACET and was used to update the aircraft groundspeed.

3.1 TASAR Alternative Trajectory Generation (Optimization Model)

In the simulation, TASAR evaluated alternative trajectories at five-minute intervals from top-of-climb to 200 nmi from the destination airport. Trajectories were evaluated against a 50% fuel / 50% time objective and TASAR advisories were rejected if they increased fuel burned or flight time (i.e., tradeoffs between fuel burn and flight time were not considered).

The use of voice for aircrew requests limited the alternative lateral trajectories to changing one or two named waypoints before reconnecting to the original trajectory. A bounding box was created for each origin-destination airport pair. All navigation aids inside the bounding box were used to generate alternative trajectories. The bounding box was based on the geographical extent of the flown trajectories between each origin-destination airport pair.

Three alternate altitudes were considered at 2,000 feet above, 2,000 feet below, and 4,000 feet below the assigned altitude. Climbing was only permitted if the aircraft was at flight level (FL 350) or below to be conservative since aircraft weight was not modeled in the simulation. Alternative trajectories consisted of lateral changes only, altitude changes only, and combination altitude and lateral changes. The aircraft in the simulation were modeled to follow their historical 4D trajectories once the aircraft were within 200 nmi of the destination airport.

3.2 TASAR Request Model

TASAR logic in the simulation implements filters to prevent the aircrew making requests that would be considered unacceptable to the controller. Requests were not made if any of the following conditions are true:

- Aircraft-aircraft conflict was predicted. The alternative trajectories generated by TASAR were probed to an eight-minute horizon to determine if there was a conflict with the surrounding traffic using a conservative ten nmi lateral and 1,000 ft vertical minimum separation shell. It was assumed that 100% of traffic was equipped with ADS-B Out since the earlier TASAR benefits study indicated that ADS-B Out equipage impacts ATC acceptability and workload but not user benefits since pilots could make a user request soon after a denied request. It was assumed that the conflict probe did not have access to flight plans and instead relied on state projections using current heading, vertical rate, and speed. Post-processing of simulation results to assess the impact of ADS-B Out equipage is discussed in Section 5.

- Aircraft-airspace hazard conflict was predicted. Alternative trajectories were also probed for conflicts with airspace hazards including special activity airspace (SAA) and severe convective weather. Airspace hazards, either weather or SAA, were defined as polygons with a floor, ceiling, and schedule for activation and deactivation. Polygons were dynamic in the sense that they are active for a defined period of time and then replaced by other polygons at different locations to mimic the motion of convective weather. If the aircraft was predicted (using the FACET predictor instance) to be inside an airspace hazard polygon, then the TASAR automation was modeled to be aware of the airspace hazard conflict.

- Aircraft had already made a request to current sector controller. Multiple requests in a sector are unreasonable and the aircrew waits until the next sector to make another request if the initial request is denied.

- Aircraft was estimated to be in handoff status once the aircraft was within approximately 20 nmi of the sector boundary. Any request received while the aircraft is in handoff status is likely to be met with the response to make the request to the next sector controller.

- Aircraft was on initial climb from origin airport and had not yet reached cruising altitude. Controllers are concerned about potential interference of the departure stream with the arrival stream, so requests are generally denied until the aircraft reaches cruising altitude.

- Aircraft is within 200 nmi of a large hub destination airport. Controllers indicated that aircraft must generally be on their assigned arrival route within 200 nmi of a large hub destination airport.

3.3 Controller Evaluation of TASAR Requests

The controller was modeled to reject an aircrew request if any of the following conditions exist.

- The aircrew request was projected to cause an aircraft-aircraft conflict. The controller had more information about the surrounding traffic than the TASAR-equipped aircraft including (1) the flight plans for all aircraft and (2) the ADS-B-equipped aircraft beyond the sixty nmi assumed ADS-B range.

- The aircrew request occurs in a sector that was experiencing traffic exceeding its monitor alert parameter value (i.e., a red sector). This was an attempt to model the phenomenon that, as traffic demand increases in their sector, controllers develop plans to cope with the rising traffic and, unless the request is consistent with the controller plan, the aircrew request is likely to be denied. Under higher traffic levels the aircrew request is less likely to be consistent with the controller plan

- The aircrew request was projected to enter an adjacent red sector. Controllers are generally not aware of red sectors elsewhere and will not consider traffic demand in other sectors when evaluating aircrew requests. However, the area manager may instruct the controller not to send traffic through an adjacent sector if the adjacent sector is currently experiencing high traffic.

The TASAR filters described previously, such as not making multiple requests to the same sector controller, were not applied again on the controller side since these types of requests would not reach the controller in the simulation.

4. Annualized TASAR Benefit Results for Virgin America

The benefits analysis focused on Virgin America operations in the continental United States. Operations performed using Airbus A320 and A319 aircraft were analyzed since these are both candidates to be equipped with TASAR.

4.1 Airport Pair Selected for Analysis

The Bureau of Transportation Statistics (BTS) T-100 Domestic Segment database[i] from April 2013 to March 2014 was used to determine the annual frequency of Virgin America operations between airport pairs by aircraft type. The departures performed and aircraft type fields in the T-100 database were used to determine annual operations by aircraft type. These annual operations were then divided by the number of aircraft of each type to obtain the operations per aircraft shown in Table 1. The airport pairs that were analyzed are shown as shaded cells. The remaining airport pairs in the continental United States were not analyzed due to time constraints.

[i] http://www.transtats.bts.gov/Fields.asp?Table_ID=311

Table 1. Annual operations per aircraft by airport pair and aircraft type. Airport pairs analyzed are shaded.

Airport 1	Airport 2	Annual Operations per Aircraft	
		A319	A320
LAX	SFO	133	104
LAS	SFO	181	64
JFK	LAX	0	81
SAN	SFO	96	55
SEA	SFO	65	58
JFK	SFO	2	64
LAX	SEA	52	48
DFW	LAX	129	19
LAX	SJC	48	46
DFW	SFO	70	30
IAD	SFO	53	28
FLL	LAX	1	39
ORD	SFO	30	35
EWR	LAX	23	41
LAS	LAX	156	10
BOS	LAX	22	33
EWR	SFO	38	37
BOS	SFO	8	36
IAD	LAX	1	34
PDX	SFO	97	15
LAX	ORD	1	32
LAX	PHL	42	19
FLL	SFO	20	18
PHL	SFO	45	7
JFK	LAS	0	17
DCA	SFO	19	12
LAX	MCO	0	17
LAX	PDX	0	11
AUS	SFO	3	14
PSP	SFO	19	3
MCO	SFO	1	4
Total annual operations by aircraft type		1,354	1,033

4.2 Simulation Fuel and Time Savings Estimates

A total of 1,554 historical Virgin America flights in July, August, and September 2012 were analyzed using the simulation platform to produce the simulation results detailed in Appendix A. The expired reroute initiative and convective weather use cases did not occur frequently (less than 10% of historical flights). This does not imply that 10% of flights were impacted by convective weather since flights may be delayed or cancelled at large hub airports until the convective weather passes and therefore TASAR would not interact with convective weather data. For the more common A320 aircraft, the expired

reroute initiative had highest average benefit (597 gallons/operation, 7.0 min/operation) and the convective weather and wind use cases had similar benefits (about 210 gallons/operation, about 2.5 min/operation).

Due to the similar convective weather use case per operation benefit as compared to the wind use case, the results are scaled without attempting to estimate the number of annual convective weather use cases. For example, 3 out of 76 historical A320 flights between New York (JFK) and Los Angeles (LAX) were classified as expired reroute initiative and each A320 operates between JFK and LAX an average of 64 times annually so (3/76)*64 = 2.5 annual cancelled expired reroute initiative use cases between JFK and SFO occurred per A320. The fuel and time raw simulation outcomes in Appendix A are scaled, and the resulting fuel and time benefits are shown in Tables 2 to 3. Benefits are a function of both the benefit per operation and number of operations, so that the New York-San Francisco (JFK-SFO) airport pair fuel benefit of about 4,900 gallons per aircraft per year is higher than the Los Angeles-San Francisco (LAX-SFO) airport pair fuel benefit of about 700 gallons per aircraft per year, even though there are almost twice as many flights between LAX-SFO than JFK-SFO.

Table 2. Annual fuel and time benefits by use case for A320.

Apt 1	Apt 2	Annual Benefit Cancelled Initiative Use Case (1)			Annual Benefit Weather Use Case (2)			Annual Benefit Wind Use Case (3)		
		Num	Fuel (Gal)	Time (Min)	Num	Fuel (Gal)	Time (Min)	Num	Fuel (Gal)	Time (Min)
JFK	SFO	2.5	0.0	5.9	5.1	230.3	21.9	56.4	4929.9	380.6
JFK	LAX	2.0	150.9	20.1	8.0	306.7	19.4	71.0	3847.1	329.4
BOS	SFO	1.9	641.6	47.4	1.9	113.0	0.0	32.2	2471.4	255.8
BOS	LAX	0.6	0.0	0.0	7.1	289.3	36.9	25.2	2443.8	154.0
FLL	LAX	1.1	0.0	13.4	2.2	0.0	4.5	35.7	1456.5	171.6
ORD	SFO	0.0	0.0	0.0	5.7	47.1	11.8	29.3	1382.0	105.5
IAD	SFO	0.0	0.0	0.0	2.7	67.0	4.7	25.3	1086.1	162.0
DFW	SFO	0.0	0.0	0.0	4.4	6.5	4.4	25.6	963.2	69.4
LAX	PHL	1.1	32.5	0.0	2.2	137.3	5.4	15.7	876.2	46.1
LAS	SFO	0.0	0.0	0.0	0.9	0.0	0.0	63.1	776.8	66.7
LAX	SFO	0.0	0.0	0.0	0.0	0.0	0.0	104.0	761.3	66.3
LAX	SEA	0.0	0.0	0.0	1.2	41.4	3.6	46.8	550.5	32.2
LAX	ORD	7.1	430.1	26.7	2.7	0.6	0.0	22.2	529.3	19.6
PHL	SFO	0.5	18.6	9.6	1.2	114.2	8.9	5.4	485.5	56.5
SAN	SFO	0.0	0.0	0.0	0.0	0.0	0.0	55.0	410.7	34.4
IAD	LAX	0.0	0.0	0.0	4.9	0.0	0.0	29.1	405.5	176.5
LAX	MCO	0.0	0.0	0.0	3.7	211.3	7.4	13.3	395.6	25.0
FLL	SFO	0.0	0.0	0.0	1.2	0.0	0.0	16.8	387.6	90.6
DFW	LAX	0.0	0.0	0.0	2.3	70.8	2.3	16.7	277.1	31.2
SEA	SFO	0.0	0.0	0.0	0.0	0.0	0.0	58.0	114.0	6.8
LAX	PDX	0.0	0.0	0.0	0.0	0.0	0.0	11.0	105.4	6.4
PDX	SFO	0.0	0.0	0.0	0.0	0.0	0.0	15.0	45.0	3.7
MCO	SFO	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0
	Sum		1273.9	123.0		1635.5	131.2		24700.3	2290.2

Table 3. Annual fuel and time benefits by use case for A319.

Apt 1	Apt 2	Annual Benefit Cancelled Initiative Use Case (1)			Annual Benefit Weather Use Case (2)			Annual Benefit Wind Use Case (3)		
		Num	Fuel (Gal)	Time (Min)	Num	Fuel (Gal)	Time (Min)	Num	Fuel (Gal)	Time (Min)
DFW	LAX	0.0	0.0	0.0	20.4	755.0	30.6	108.6	5120.6	234.2
PHL	SFO	3.0	119.8	61.5	7.5	734.1	57.0	34.5	3121.0	363.0
DFW	SFO	0.0	0.0	0.0	11.7	494.2	25.7	58.3	2919.5	142.3
LAS	SFO	0.0	0.0	0.0	0.0	0.0	0.0	181.0	2249.5	181.0
LAX	PHL	2.4	71.9	0.0	4.8	303.5	12.0	34.8	1936.9	102.0
BOS	LAX	0.4	0.0	0.0	4.7	192.8	24.6	16.8	1629.2	102.7
LAX	SEA	0.0	0.0	0.0	5.0	107.1	2.5	47.0	1351.3	61.9
ORD	SFO	0.0	0.0	0.0	4.9	40.3	10.1	25.1	1184.6	90.5
SAN	SFO	0.0	0.0	0.0	0.0	0.0	0.0	96.0	1135.1	96.0
LAX	SFO	0.0	0.0	0.0	0.0	0.0	0.0	133.0	1133.3	105.0
FLL	SFO	0.0	0.0	0.0	1.4	0.0	0.0	18.6	430.7	100.7
PDX	SFO	0.0	0.0	0.0	0.0	0.0	0.0	97.0	291.2	23.7
SEA	SFO	0.0	0.0	0.0	0.0	0.0	0.0	65.0	127.8	7.6
JFK	SFO	0.1	0.0	0.0	0.4	0.0	0.6	1.5	107.8	13.4
FLL	LAX	0.0	0.0	0.3	0.1	0.0	0.1	0.9	37.3	4.4
LAX	ORD	0.2	3.7	0.3	0.1	0.0	0.0	0.7	13.6	1.3
IAD	SFO	0.0	0.0	0.0	0.0	0.0	0.0	53.0	0.0	773.8
BOS	SFO	0.0	0.0	0.0	0.3	1.6	1.1	7.7	0.0	54.6
IAD	LAX	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
	Sum		195.5	62.2		2628.6	164.3		22789.5	2458.0

4.3 Estimating Annualized Cost Savings

Virgin America indicated that $3.03 is the current fuel cost being used in similar economic analysis to convert fuel savings to cost savings. A fuel cost of $3.03/gallon was multiplied by fuel savings for the three use cases (i.e., 195.5 + 2628.6 + 22789.5 = 25613.1 gallons for A319, rounded down to 25,000 gallons) and the number of aircraft of that type to obtain a total annual savings of $4.27 million per year as shown in Table 4.

Table 4. Summary of fuel cost savings calculation.

Aircraft Type	Number of Aircraft of Type	Annual Ops Simulated / Estimated Annual Ops [i]	Annual Fuel Savings per Aircraft (gallons)	Fuel Cost	Fuel Cost Savings for All Aircraft of Type
A320	43	852/1033	27,000	$3.03	$3,517,830
A319	10	1047/1354	25,000	$3.03	$757,500
				Sum	$4,275,330

[i] Already used in fuel savings column to the right. Shown to illustrate that different amount of operations for each aircraft type cause difference in benefits.

BTS Form 41[i] financial data was used to obtain maintenance and depreciation costs in order to convert time savings to cost savings. Schedule P-5.2 reports the total maintenance, depreciation, and aircraft hours by aircraft type for Virgin America and other large carriers. These figures were used to estimate maintenance and depreciation costs per minute by aircraft type shown in Table 5. These costs were used to convert time savings into annual maintenance ($740,005) and depreciation ($72,090) savings.

Virgin America incurs other costs, including crew costs, which are based on actual block time. Flight crews are paid based on the scheduled block time or actual block time, whichever is greater. TASAR was found to reduce actual block time above the scheduled block time by an average of about 0.4 minutes per flight out of an average time savings per flight of 2.8 minutes to 3.3 minutes for the A320 and A319 respectively. These time savings result in an additional crew cost savings that were not quantified but represent a potential additional TASAR benefit. The time savings may also result in increased customer satisfaction over time, but no attempt was made to quantify that benefit.

Table 5. Summary of maintenance and depreciation savings calculation.

Aircraft Type	Number of Aircraft of Type	Time Savings per Aircraft (min)	Maintenance Cost per min	Maintenance Cost Savings for All Aircraft of Type	Depreciation Cost per min	Depreciation Cost Savings for All Aircraft of Type
A320	43	2,500	$5.51	$592,325	$0.54	$58,050
A319	10	2,600	$5.68	$147,680	$0.54	$14,040
			Sum	$740,005	Sum	$72,090

The fuel, maintenance, and depreciation costs were added to obtain a total cost savings of about $5.09 million annually ($4,275,330 + $740,005 + $72,090 = $5,087,425).

These benefits were a result of lateral (58% of requests), vertical (5% of requests), and combination lateral and vertical TASAR requests (37% of requests). A breakdown of these percentages by aircraft type is included in Appendix B.

5. ATC Impacts

A total of 6,038 TASAR requests were simulated of which 470 (8%) were rejected due to conflicts (305) and other factors (165). Recall that it was assumed in the simulation that 100% of traffic aircraft was equipped with ADS-B Out. However, this did not result in TASAR detecting all conflicts since TASAR does not have as much information as the controller. A total of 7,403 requests which, if approved, would save fuel and time were not made by TASAR aircraft since they were predicted to be unapproveable to ATC including 1,162 due to conflicts. If the surrounding traffic was not equipped with ADS-B Out or the TASAR ownship was not equipped with ADS-B In, then this would imply that approximately (470 + 1,162) / (6,038 + 1,162) = 23% would reasonably be expected to be rejected. The (470 + 1,162) includes the original 470 rejections and the 1,162 requests not made since they were predicted by TASAR to contain conflicts and, without both

[i] http://www.transtats.bts.gov/Tables.asp?DB_ID=135

surrounding traffic being equipped with ADS-B Out and TASAR ownship being equipped without ADS-B In, these conflicts would not be known to TASAR and the requests would have been made. Therefore, while the previous benefit study indicated that ADS-B Out equipage rate and TASAR ownship ADS-B In equipage does not significantly impact benefits, they are important in reducing nuissance requests that increase controller workload. Also, while an attempt has been made to model controller behavior as closely as possible, there is still uncertainty as to whether a controller will or will not grant a request. Even if a request would cause a conflict, the controller may hold onto the request and wait for the traffic to pass and be clear of projected conflicts before granting the request.

It was found that Virgin America TASAR requests were spread across the country and not concentrated in a single Air Route Traffic Control Center (ARTCC). The two sectors that experienced the most TASAR requests at about 3% of total requests each, ZOA33 and ZOA34, are high altitude (FL 240+) sectors east of San Francisco. ZLC45, which lies on ZOA33's eastern border, is the sector with the next highest number of requests . The higher number of requests in ZOA33, ZOA34, and ZLC45 is due to east-west traffic going to and from Virgin America's hub at San Francisco (SFO).

Due to computational reasons, there was only one TASAR aircraft active in the simulation at once, and so the following procedure, which also takes into account that not all airport pairs were simulated, was used to estimate daily requests by sector across multiple simulation runs. The following statistics were used to derive (1) the expected daily TASAR requests per day and (2) TASAR requests not made due to conflicts: average daily Virgin America continental US flights (159) derived from Table 1, the number of flights simulated (1,554), the number of TASAR requests by sector, and TASAR requests not made due to conflicts (i.e., filtered) by sector. For example, ZOA33 had 203 requests reported in the simulation so it was estimated that (203)(159/1554) = 21 requests per day occur in ZOA33. The requests not made (filtered) were used to approximate the number of requests if the aircraft was not equipped with ADS-B In. These filtered requests were added to requests made to approximate the number of requests if the TASAR aircraft was not equipped with ADS-B In or traffic aircraft were not equipped with ADS-B Out. A summary of this calculation is shown in Table 6 for the ten sectors receiving the most TASAR requests.

Table 6. TASAR requests per day by sector where TASAR request occurs.

Sector where TASAR Request Occurs	TASAR Requests (1)	TASAR Requests not Made due to Conflicts (2)	Requests Made + Requests not Made: (1) + (2) = (3)	Requests per Day with ADS-B In: (1) * (159 / 1554)	Requests per Day without ADS-B In: (3) * (159 / 1554)
ZOA33	203	20	223	21	23
ZOA34	199	8	207	20	21
ZLC45	154	87	241	16	25
ZDV24	105	38	143	11	15
ZMP42	103	18	121	11	12
ZSE14	97	42	139	10	14
ZLA39	90	8	98	9	10

Sector where TASAR Request Occurs	TASAR Requests (1)	TASAR Requests not Made due to Conflicts (2)	Requests Made + Requests not Made: (1) + (2) = (3)	Requests per Day with ADS-B In: (1) * (159 / 1554)	Requests per Day without ADS-B In: (3) * (159 / 1554)
ZLC34	84	29	113	9	12
ZLA37	83	2	85	8	9
ZOA31	81	54	135	8	14

Requests per hour by sector was approximated by binning the TASAR request times into hours and scaling by requests per day (e.g., scale ZOA33 hourly results by 21/203) to account for the fact that flights were simulated across multiple days. Table 7 shows hourly results for the three sectors with the most requests which indicate that 2 to 4 requests per sector occur during the peak hours between about 9 AM and 2 PM. If necessary, the peak requests of 2 to 4 requests per sector per hour could potentially be managed through coordination with dispatchers or another procedure.

Table 7. TASAR requests per hour by sector where TASAR request occurs.

Hour of Request (Pacific time)	ZOA33 Average Requests in Hour	ZOA34 Average Requests in Hour	ZLC45 Average Requests in Hour
0	0.2	0.0	0.2
1	0.1	0.2	0.0
2	0.0	0.0	0.1
3	0.0	0.0	0.0
4	0.0	0.0	0.0
5	0.0	0.0	0.0
6	0.0	0.0	0.0
7	0.2	0.2	0.8
8	2.1	1.2	2.7
9	2.1	3.5	0.8
10	1.2	1.2	1.0
11	2.9	1.9	2.9
12	2.3	2.2	2.4
13	1.4	2.1	0.5
14	3.0	2.2	1.7
15	1.6	1.2	1.1
16	0.3	0.9	0.1
17	0.0	0.0	0.0
18	0.1	0.3	0.0
19	0.0	0.4	0.1
20	1.1	0.7	0.5
21	1.5	1.6	0.4
22	0.7	0.5	0.3
23	0.1	0.1	0.1

6. Future Work

A TASAR flight trial is planned for 2015 with one of the objectives to develop a methodology to verify the accuracy of the TASAR Traffic Aware Planner (TAP) software computed outcomes. This method could be applied to the simulation benefits results presented in this report to verify that benefits are not systematically being over or under reported. Following that flight test, it is expected that TASAR will be placed on a revenue flight so the method can be applied and suitable adjustments made to TAP and the benefits assessment.

Observations at ATC facilities are also planned which could be used to refine controller models in the simulation to better estimate the conditions under which a TASAR request is accepted or rejected.

7. References

[1]Henderson, J., Wing, D.J., and Idris, H., "Preliminary Benefits Assessment of Traffic Aware Strategic Aircrew Requests (TASAR)", *AIAA 12th Aviation Technology, Integration, and Operations Conference (ATIO)*, Indianapolis, IN, September 2012.

Appendix A: Simulation Fuel and Time Savings

This appendix includes fuel and time savings output from the fast-time simulation platform for each aircraft type.

Table 8. A320 simulation results.

Airport 1	Airport 2	Use Case	Flights Simulated	Time Savings (min)	Fuel Savings (lbs)
KBOS	KLAX	Cx Reroute TMI	1	0.0	0.0
KBOS	KLAX	Weather	11	-5.2	-278.0
KBOS	KLAX	Wind	39	-6.1	-662.4
KBOS	KLAX	All	51	-5.8	-565.3
KBOS	KSFO	Cx Reroute TMI	1	-25.0	-2316.3
KBOS	KSFO	Weather	1	1.0	-407.9
KBOS	KSFO	Wind	17	-7.9	-524.8
KBOS	KSFO	All	19	-8.4	-612.9
KDFW	KLAX	Cx Reroute TMI	0	0.0	0.0
KDFW	KLAX	Weather	3	-1.0	-212.5
KDFW	KLAX	Wind	22	-1.9	-113.3
KDFW	KLAX	All	25	-1.8	-125.2
KDFW	KSFO	Cx Reroute TMI	0	0.0	0.0
KDFW	KSFO	Weather	8	-1.0	-9.9
KDFW	KSFO	Wind	46	-2.7	-257.8
KDFW	KSFO	All	54	-2.5	-221.1
KFLL	KLAX	Cx Reroute TMI	1	-12.0	0.0
KFLL	KLAX	Weather	2	-2.0	0.0
KFLL	KLAX	Wind	32	-4.8	-279.4
KFLL	KLAX	All	35	-4.9	-191.9
KIAD	KLAX	Cx Reroute TMI	0	0.0	0.0
KIAD	KLAX	Weather	3	0.0	0.0
KIAD	KLAX	Wind	18	-6.1	-95.2
KIAD	KLAX	All	21	-5.1	-73.0
KIAD	KSFO	Cx Reroute TMI	1	-36.0	-6893.6
KIAD	KSFO	Weather	4	-1.8	-172.0
KIAD	KSFO	Wind	53	-7.1	-206.4
KIAD	KSFO	All	58	-7.2	-319.3
KJFK	KLAX	Cx Reroute TMI	3	-10.0	-514.0
KJFK	KLAX	Weather	12	-2.4	-261.2
KJFK	KLAX	Wind	106	-4.6	-370.8
KJFK	KLAX	All	121	-4.6	-363.5
KJFK	KSFO	Cx Reroute TMI	3	-2.3	141.7
KJFK	KSFO	Weather	6	-4.3	-311.8
KJFK	KSFO	Wind	67	-6.7	-597.7
KJFK	KSFO	All	76	-6.4	-545.9
KLAS	KSFO	Cx Reroute TMI	0	0.0	0.0

Airport 1	Airport 2	Use Case	Flights Simulated	Time Savings (min)	Fuel Savings (lbs)
KLAS	KSFO	Weather	1	0.0	0.0
KLAS	KSFO	Wind	70	-1.1	-84.2
KLAS	KSFO	All	71	-1.0	-83.0
KLAX	KMCO	Cx Reroute TMI	0	0.0	0.0
KLAX	KMCO	Weather	7	-2.0	-388.7
KLAX	KMCO	Wind	25	-1.9	-203.7
KLAX	KMCO	All	32	-1.9	-244.2
KLAX	KORD	Cx Reroute TMI	8	-3.8	-413.7
KLAX	KORD	Weather	3	0.7	-1.6
KLAX	KORD	Wind	25	-0.9	-162.9
KLAX	KORD	All	36	-1.4	-205.2
KLAX	KPDX	Cx Reroute TMI	0	0.0	0.0
KLAX	KPDX	Weather	0	0.0	0.0
KLAX	KPDX	Wind	60	-0.6	-65.5
KLAX	KPDX	All	60	-0.6	-65.5
KLAX	KPHL	Cx Reroute TMI	2	0.0	-205.0
KLAX	KPHL	Weather	4	-2.5	-432.5
KLAX	KPHL	Wind	29	-2.9	-380.7
KLAX	KPHL	All	35	-2.7	-376.6
KLAX	KSEA	Cx Reroute TMI	0	0.0	0.0
KLAX	KSEA	Weather	2	-3.0	-232.8
KLAX	KSEA	Wind	77	-0.7	-80.5
KLAX	KSEA	All	79	-0.7	-84.3
KLAX	KSFO	Cx Reroute TMI	0	0.0	0.0
KLAX	KSFO	Weather	0	0.0	0.0
KLAX	KSFO	Wind	113	-0.6	-50.1
KLAX	KSFO	All	113	-0.6	-50.1
KMCO	KSFO	Cx Reroute TMI	0	0.0	0.0
KMCO	KSFO	Weather	0	0.0	0.0
KMCO	KSFO	Wind	1	0.0	0.0
KMCO	KSFO	All	1	0.0	0.0
KORD	KLAX	Cx Reroute TMI	8	-3.8	-413.7
KORD	KLAX	Weather	3	0.7	-1.6
KORD	KLAX	Wind	25	-0.9	-162.9
KORD	KLAX	All	36	-1.4	-205.2
KORD	KSEA	Cx Reroute TMI	0	0.0	0.0
KORD	KSEA	Weather	0	0.0	0.0
KORD	KSEA	Wind	0	0.0	0.0
KORD	KSEA	All	0	0.0	0.0
KORD	KSFO	Cx Reroute TMI	0	0.0	0.0
KORD	KSFO	Weather	13	-2.1	-56.6
KORD	KSFO	Wind	67	-3.9	-374.1
KORD	KSFO	All	80	-3.6	-322.5
KPDX	KPHX	Cx Reroute TMI	0	0.0	0.0

Airport 1	Airport 2	Use Case	Flights Simulated	Time Savings (min)	Fuel Savings (lbs)
KPDX	KPHX	Weather	0	0.0	0.0
KPDX	KPHX	Wind	0	0.0	0.0
KPDX	KPHX	All	0	0.0	0.0
KPDX	KSFO	Cx Reroute TMI	0	0.0	0.0
KPDX	KSFO	Weather	0	0.0	0.0
KPDX	KSFO	Wind	41	-0.2	-20.5
KPDX	KSFO	All	41	-0.2	-20.5
KPHL	KSFO	Cx Reroute TMI	2	-20.5	-273.2
KPHL	KSFO	Weather	5	-7.6	-669.5
KPHL	KSFO	Wind	23	-10.5	-618.8
KPHL	KSFO	All	30	-10.7	-604.2
KSAN	KSFO	Cx Reroute TMI	0	0.0	0.0
KSAN	KSFO	Weather	0	0.0	0.0
KSAN	KSFO	Wind	99	-0.6	-51.1
KSAN	KSFO	All	99	-0.6	-51.1
KSEA	KSFO	Cx Reroute TMI	0	0.0	0.0
KSEA	KSFO	Weather	0	0.0	0.0
KSEA	KSFO	Wind	94	-0.1	-13.4
KSEA	KSFO	All	94	-0.1	-13.4
All	All	Cx Reroute TMI	30	-7.0	-596.7
All	All	Weather	88	-2.5	-214.6
All	All	Wind	1149	-2.7	-211.0
All	All	All	1267	-2.8	-218.5

Table 9. A319 simulation results.

Airport 1	Airport 2	Use Case	Flights Simulated	Time Savings (min)	Fuel Savings (lbs)
KBOS	KSFO	Cx Reroute TMI	0	0.0	0.0
KBOS	KSFO	Weather	1	-4.0	-40.0
KBOS	KSFO	Wind	28	-7.1	0.0
KBOS	KSFO	All	29	-7.0	0.0
KDFW	KLAX	Cx Reroute TMI	0	0.0	0.0
KDFW	KLAX	Weather	6	-1.5	-253.5
KDFW	KLAX	Wind	32	-2.2	-322.4
KDFW	KLAX	All	38	-2.1	-311.5
KDFW	KSFO	Cx Reroute TMI	0	0.0	0.0
KDFW	KSFO	Weather	5	-2.2	-289.8
KDFW	KSFO	Wind	25	-2.4	-342.3
KDFW	KSFO	All	30	-2.4	-333.6
KFLL	KSFO	Cx Reroute TMI	0	0.0	0.0
KFLL	KSFO	Weather	2	-1.5	0.0
KFLL	KSFO	Wind	27	-5.4	-158.2

Airport 1	Airport 2	Use Case	Flights Simulated	Time Savings (min)	Fuel Savings (lbs)
KFLL	KSFO	All	29	-5.1	-146.3
KIAD	KLAX	Cx Reroute TMI	0	0.0	0.0
KIAD	KLAX	Weather	0	0.0	0.0
KIAD	KLAX	Wind	1	-21.0	0.0
KIAD	KLAX	All	1	-21.0	0.0
KIAD	KSFO	Cx Reroute TMI	1	-2.0	-19.6
KIAD	KSFO	Weather	0	0.0	0.0
KIAD	KSFO	Wind	10	-13.5	-15.1
KIAD	KSFO	All	11	-12.5	-15.5
KJFK	KSFO	Cx Reroute TMI	1	0.0	0.0
KJFK	KSFO	Weather	3	-1.7	0.0
KJFK	KSFO	Wind	12	-8.9	-491.5
KJFK	KSFO	All	16	-7.0	-325.0
KLAS	KSFO	Cx Reroute TMI	0	0.0	0.0
KLAS	KSFO	Weather	0	0.0	0.0
KLAS	KSFO	Wind	30	-1.0	-85.0
KLAS	KSFO	All	30	-1.0	-85.0
KLAX	KORD	Cx Reroute TMI	6	-1.7	-131.5
KLAX	KORD	Weather	3	-1.7	0.0
KLAX	KORD	Wind	22	-1.8	-130.8
KLAX	KORD	All	31	-1.8	-114.5
KLAX	KSEA	Cx Reroute TMI	0	0.0	0.0
KLAX	KSEA	Weather	2	-0.5	-147.9
KLAX	KSEA	Wind	19	-1.3	-196.5
KLAX	KSEA	All	21	-1.2	-191.8
KLAX	KSFO	Cx Reroute TMI	0	0.0	0.0
KLAX	KSFO	Weather	0	0.0	0.0
KLAX	KSFO	Wind	19	-0.8	-58.3
KLAX	KSFO	All	19	-0.8	-58.3
KORD	KLAX	Cx Reroute TMI	6	-1.7	-131.5
KORD	KLAX	Weather	3	-1.7	0.0
KORD	KLAX	Wind	22	-1.8	-130.8
KORD	KLAX	All	31	-1.8	-114.5
KSAN	KSFO	Cx Reroute TMI	0	0.0	0.0
KSAN	KSFO	Weather	0	0.0	0.0
KSAN	KSFO	Wind	1	-1.0	-80.9
KSAN	KSFO	All	1	-1.0	-80.9
All	All	Cx Reroute TMI	14	-1.6	-114.1
All	All	Weather	25	-1.7	-132.2
All	All	Wind	248	-3.6	-171.1
All	All	All	287	-3.3	-161.4

Appendix B: TASAR Request Trajectory Change Types

Table 10 summarizes the percentage of requests that are lateral, vertical, or combination lateral and vertical by aircraft type. The count of requests by aircraft type in the simulation are shown in the top half of the table and then shown as percentages in the lower half of the table.

Table 10. Percentage of lateral, vertical, and combination lateral and vertical by aircraft type.

Trajectory Change Type	A320	A319	All
Lateral	2,679	359	3,038
Vertical Lower	135	28	163
Vertical Higher	92	14	106
Lateral and Lower	894	233	1,127
Lateral and Higher	628	197	825
Sum	4,428	831	5,259
Lateral (%)	60.5%	43.2%	57.8%
Vertical Lower (%)	3.0%	3.4%	3.1%
Vertical Higher (%)	2.1%	1.7%	2.0%
Lateral and Lower (%)	20.2%	28.0%	21.4%
Lateral and Higher (%)	14.2%	23.7%	15.7%
Sum	100.0%	100.0%	100.0%

Virgin America Traffic Aware Strategic Aircrew Requests (TASAR) Benefits Assessment

Jeff Henderson
Engility Corporation

David Wing
NASA Langley

Your Mission. Our Commitment.

San Francisco, CA

October 2014

Overview of benefits assessment

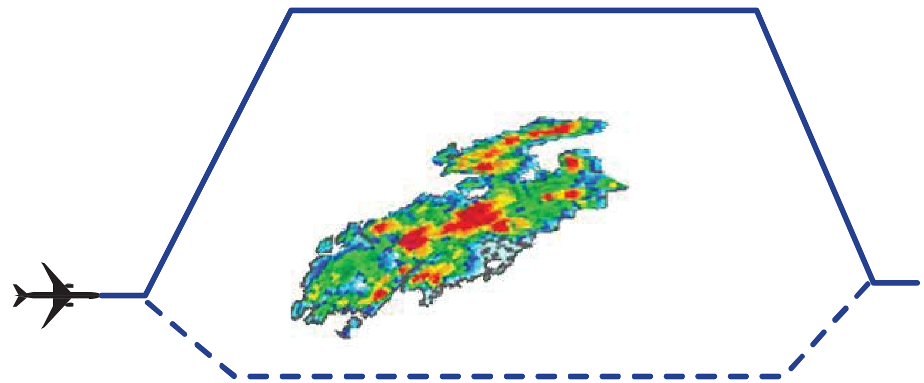
- **TASAR use-cases analyzed**
- **Method used to estimate fuel and time benefits**
- **Results**
  - *Benefits for Virgin America routes*
  - *ATC impacts*
- **Future work**
  - *Flight test to validate methodology*

Quantified benefits of three use cases

1. **Lateral change after reroute initiative has ended**

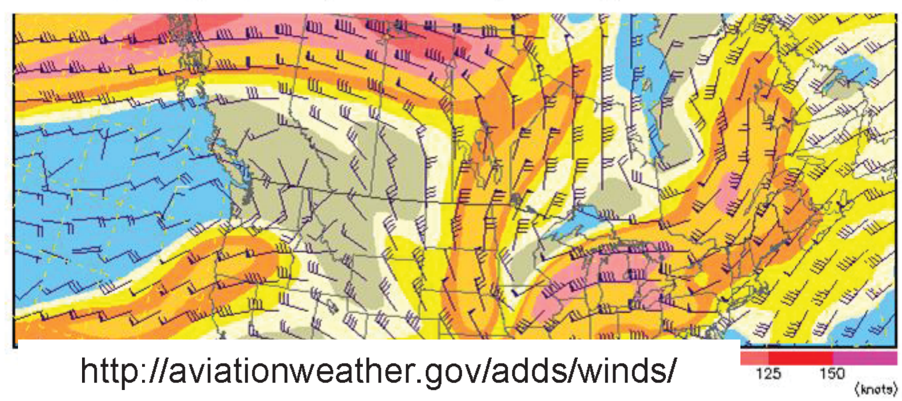
http://www.fly.faa.gov/PLAYBOOK/pbindex.html

2. **Lateral change avoiding convective weather**



3. **Change to more wind-optimal trajectory (lateral, altitude, or combination)**

Wind speed (kts) at 30,000 ft MSL (300 mb)



http://aviationweather.gov/adds/winds/

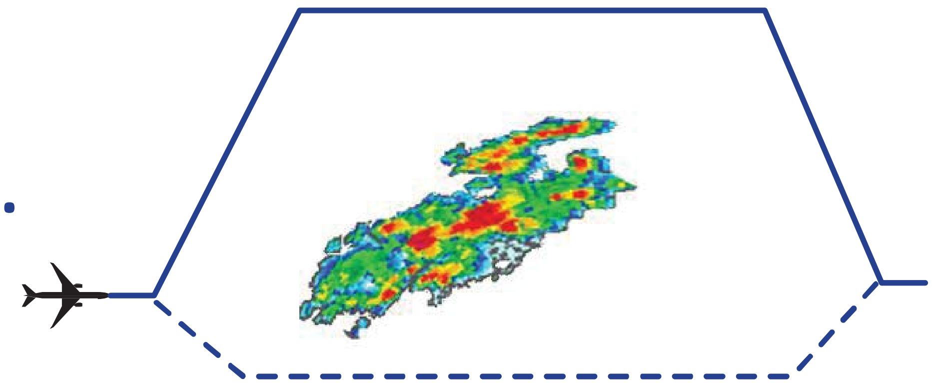
- **Other use cases (not modeled) expected to provide additional benefit**

Quantified benefits of three use cases

1. **Aircraft part of re-route initiative that has ended classified as (1).**

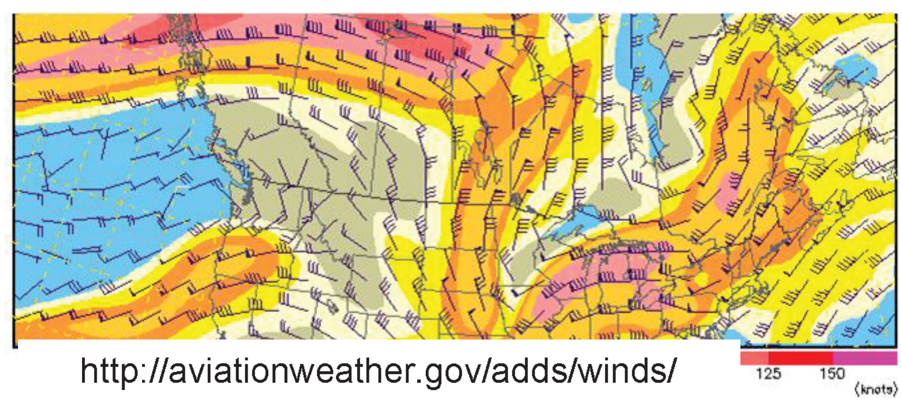
http://www.fly.faa.gov/PLAYBOOK/pbindex.html

2. **Aircraft with alternative route through convective weather classified as (2) if not part of (1).**



3. **Remaining aircraft not in (1) or (2) classified as (3). TASAR uses RAP winds to convert groundspeed to/from true airspeed.**

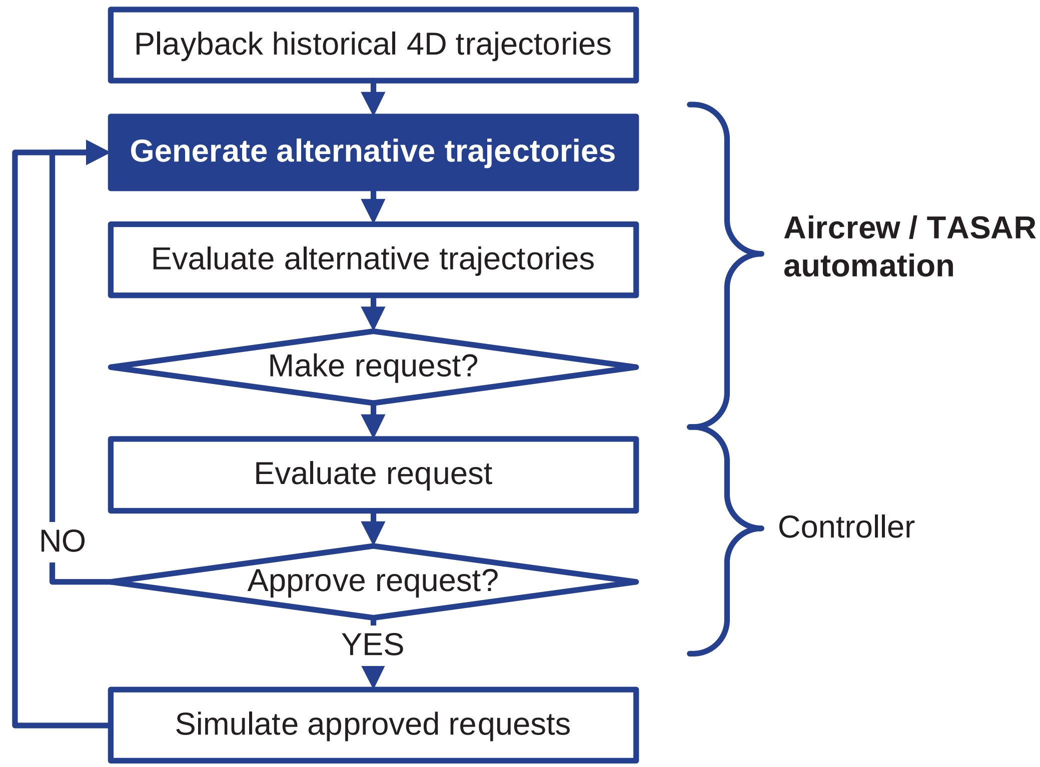
Wind speed (kts) at 30,000 ft MSL (300 mb)



http://aviationweather.gov/adds/winds/

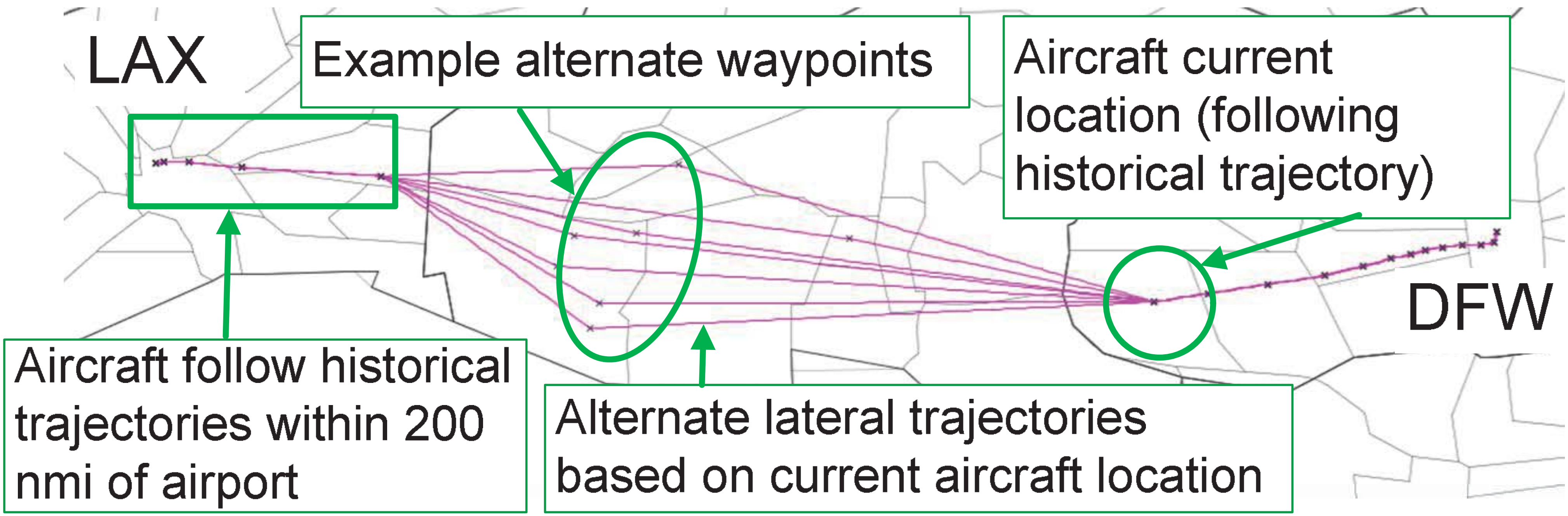
Method to estimate fuel and time benefits

- **Baseline**
  - *Aircraft follow historical 4D trajectories derived from ASA radar tracks*
- **With TASAR**
  - *Aircraft follow historical 4D trajectories until TASAR request granted*
  - *Aircrew model uses TASAR to consider fuel, time, and ATC acceptability*
  - *Controller model evaluates request using more traffic info*



Aircrew generates request according to their objectives

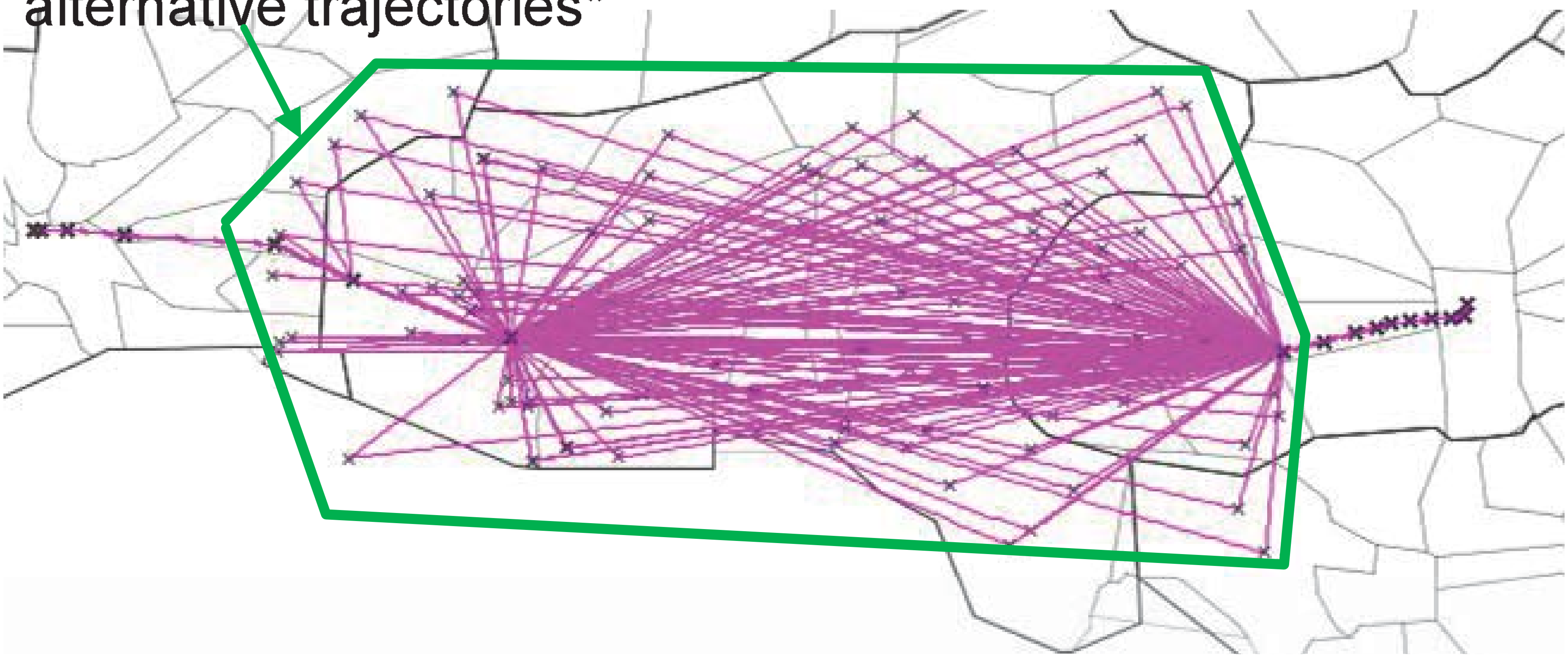
- **Objective used in simulation: 50% fuel, 50% time**
  - *Constraint: fuel and time savings both ≥ 0 (i.e., exclude solutions that decrease fuel burned but increase flight time and vice versa)*
- **Voice communication limits requests to two named waypoints**
- **Considered lateral, altitude, and combination lateral and altitude trajectory changes**



Alternative waypoints limited for computational reasons

- **Bounding box used to limit alternative trajectories**
- **Box limits based on historical tracks between airport pair**

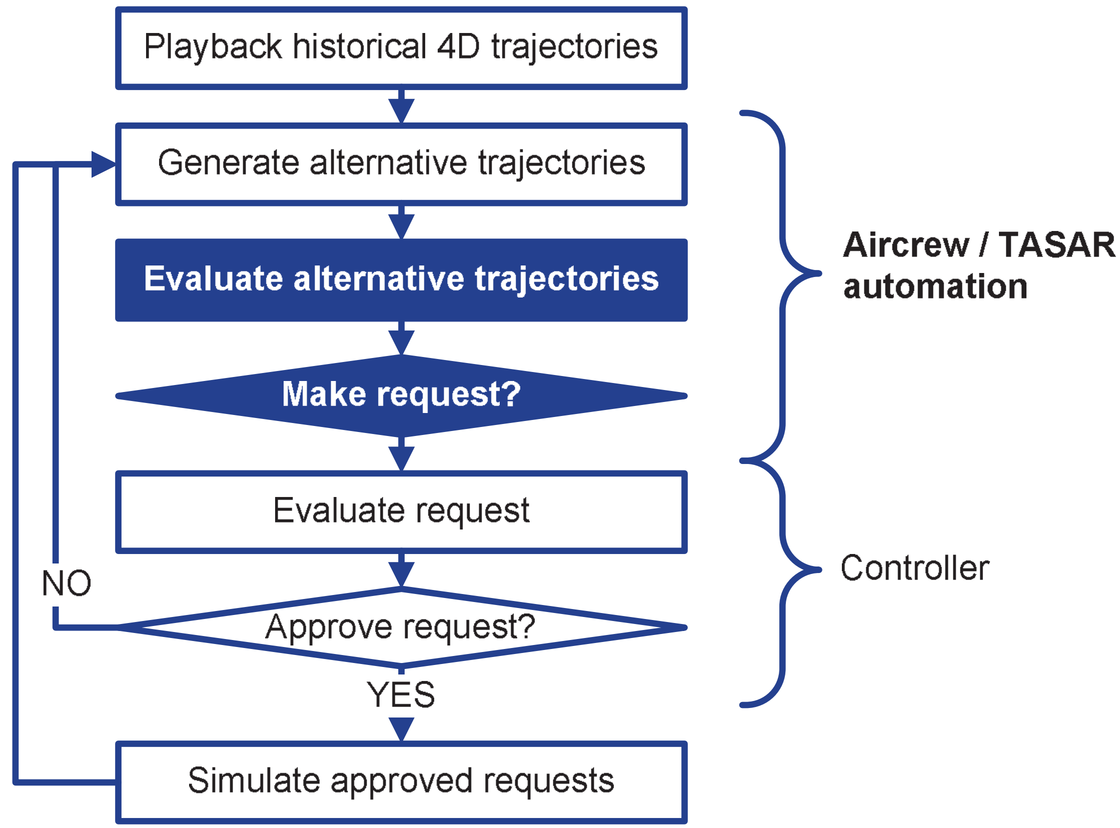
All named waypoints inside bounding box used to generate alternative trajectories*



* **Note: Additional alternative waypoints not shown in figure.**

Aircrew decides whether to make request based on estimate of controller acceptability

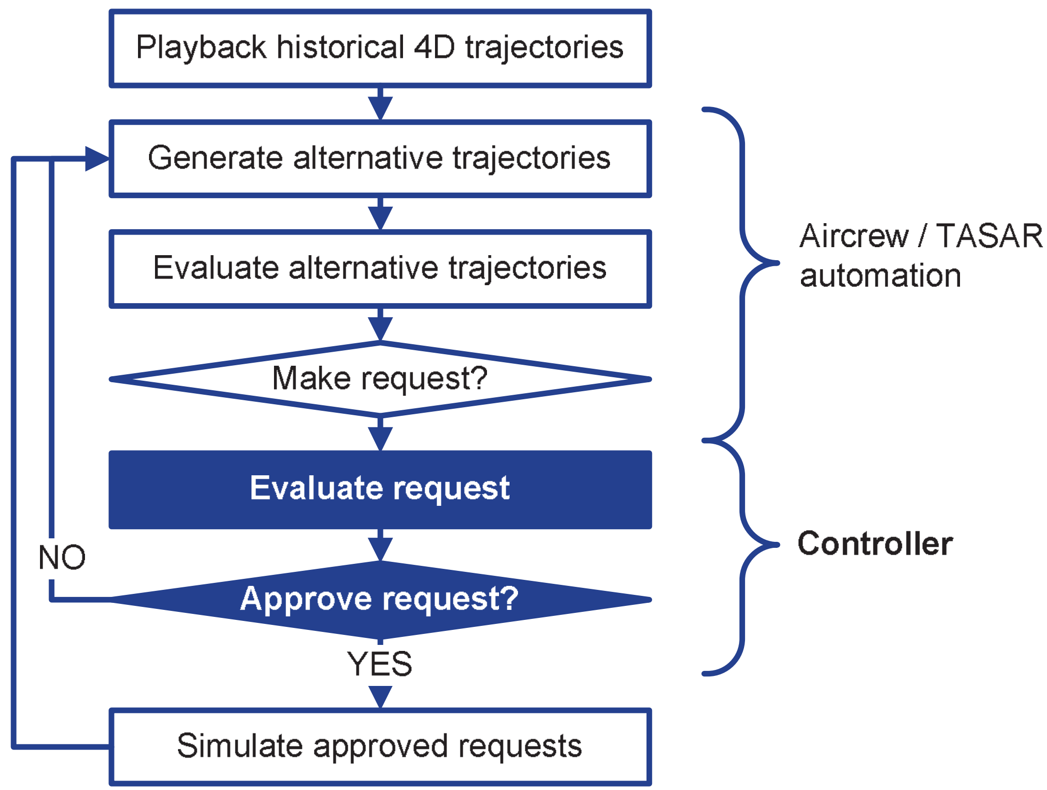
- **Aircrew request withheld if:**
  - *Aircraft-aircraft conflict (depends on ADS-B equipment)*
  - *Aircraft-airspace hazard conflict*
  - *Already made request to current controller*
  - *Request has no impact on current sector*
  - *Aircraft in handoff status – 20 nmi from sector boundary*
  - *Aircraft on initial climb – potential interference with arrival traffic*
  - *Aircraft within 200 nmi of large hub destination airport*



- **Benefit results assume 100% ADS-B OUT equipage**
  - *Earlier study indicated that ADS-B OUT equipage impacts ATC acceptability but not TASAR benefits*
  - *ATC impacts included later in presentation*

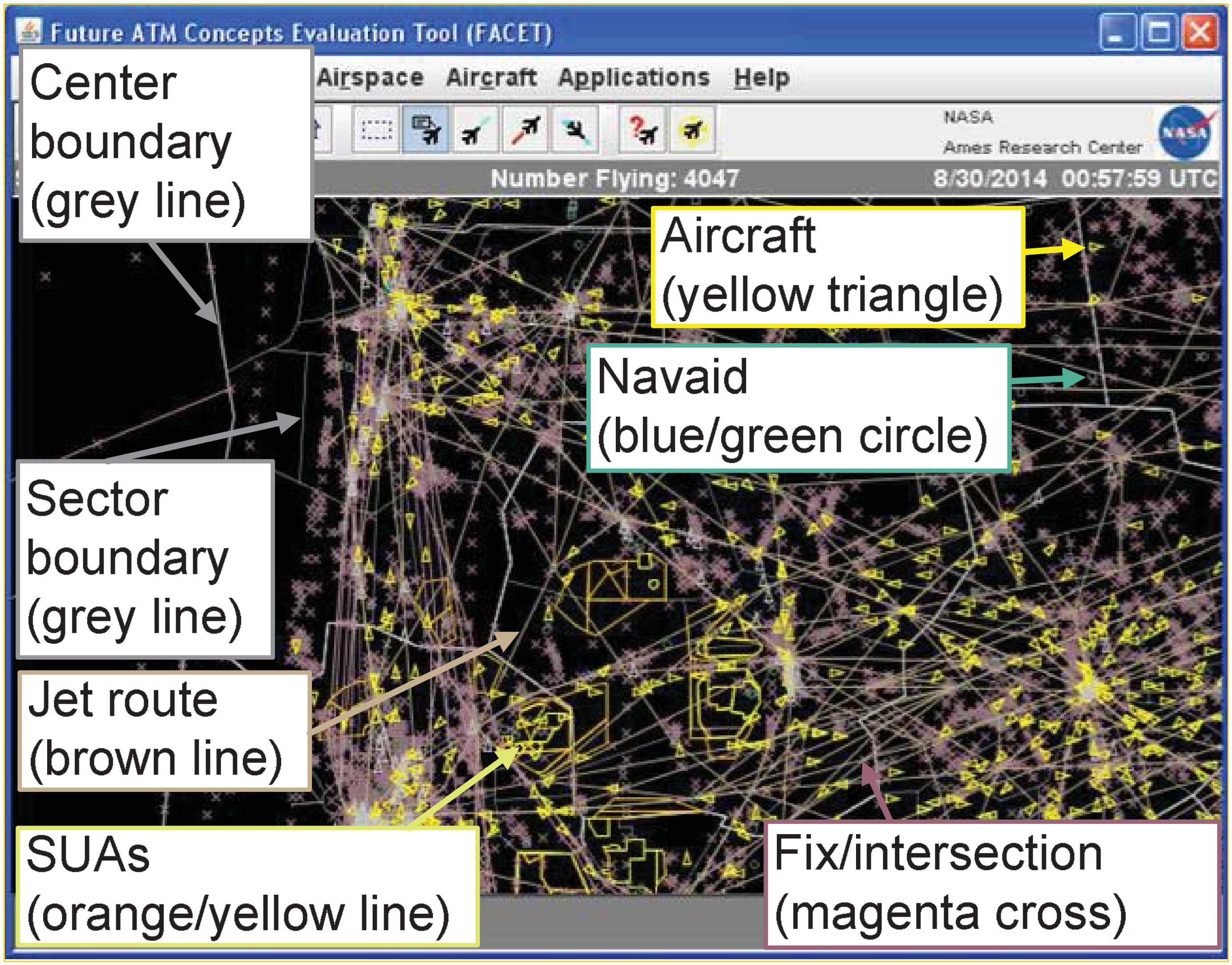
Controller evaluates requests against ATC objectives using ATC knowledge

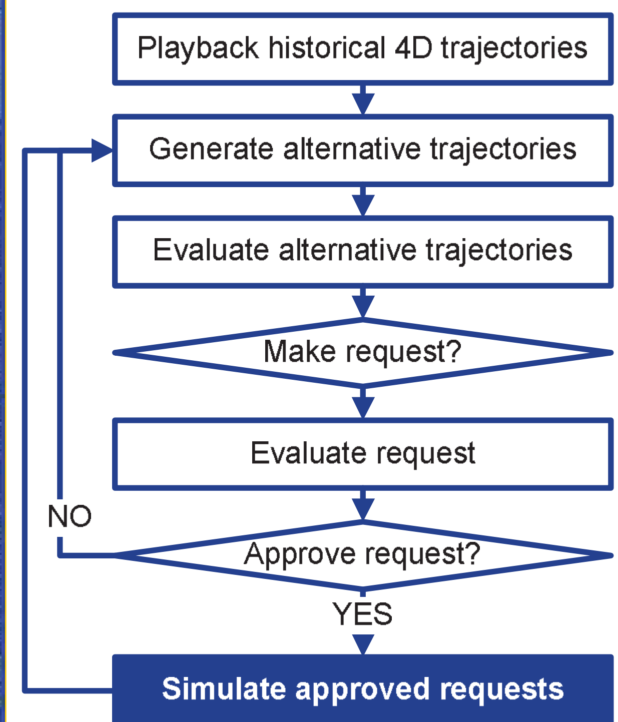
- **Additional ATC knowledge**
  - *Aircraft intent (flight plans)*
  - *ADS-B Aircraft outside 60 nmi assumed ADS-B range*
  - *Demand exceeding monitor alert parameter (MAP) – red sectors*



Fast-time simulation used for both baseline and TASAR scenarios

- **Platform leverages Future ATM Concept Evaluation Tool (FACET)**
  - *Aircraft performance model*
  - *Airspace*



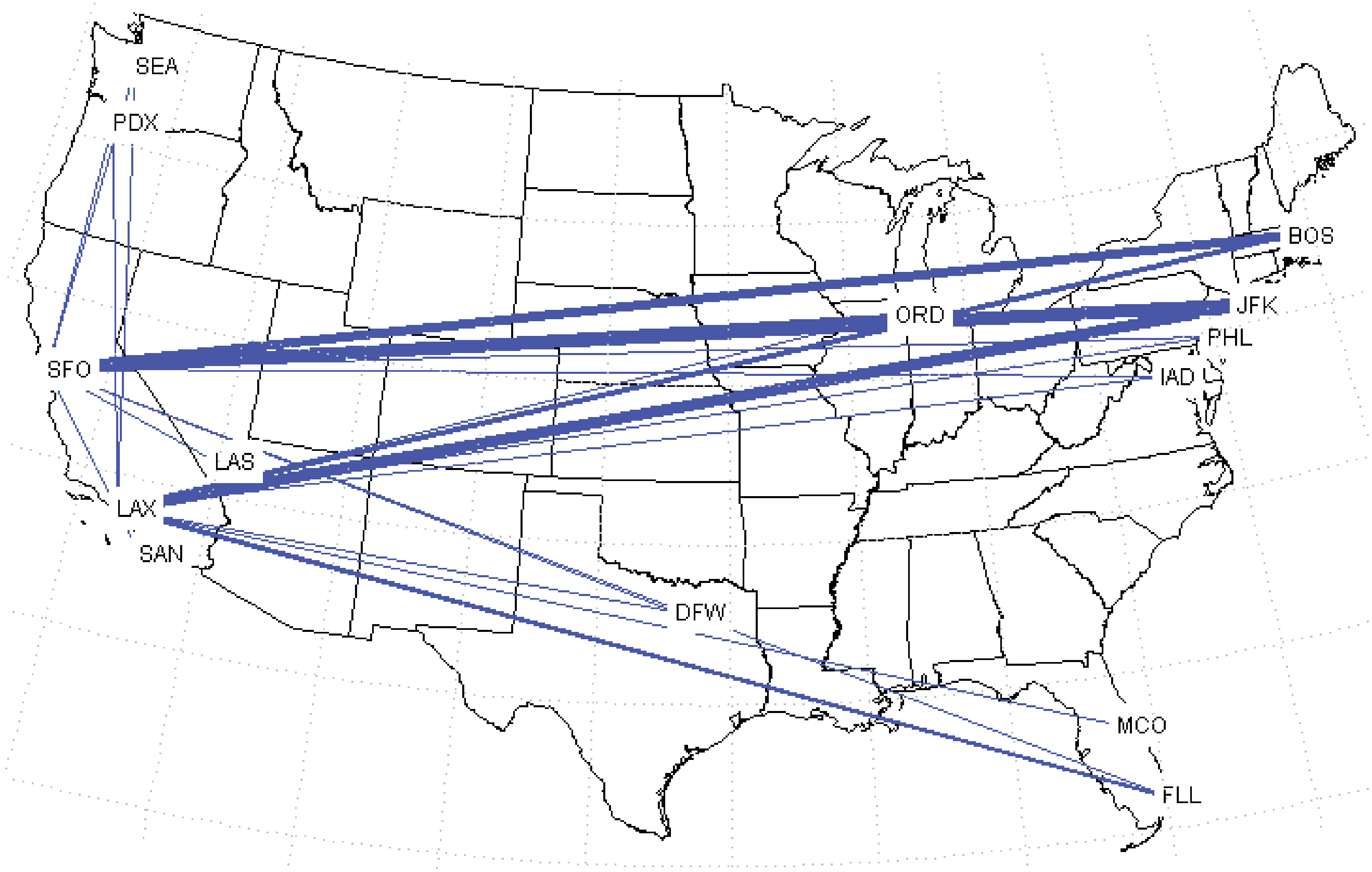


Results overview

- **Fuel and time benefits for airport pairs by aircraft type shown in following order**
  - *A320*
  - *A319*
- **Summary of annual fuel and time benefits:**
  - *by aircraft type, and*
  - *across all aircraft*

A320 benefits by airport pair

- **Line thickness represents relative fuel benefit per aircraft per year between airports**
- **TASAR is expected to have highest benefit for A320 operations between New York (JFK) and San Francisco (SFO)**
  - ***Benefit = (fuel benefit per operation) * (estimated annual operations between airport pair per aircraft)***



Airport pairs with highest expected annual fuel benefits for A320 when using TASAR

- Data source for annual operations: BTS T100 database derived from Form 41 air carrier reported operations (divide annual ops by number of aircraft to obtain ops per aircraft)
- Table shows results for wind use case which occurs most frequently
- Convective weather and expired TMI use cases included for completeness

Airport 1	Airport 2	Per Operation Benefit		Annual Benefit		
		Fuel (gal)	Time (min)	Ops per A320	Fuel (gal)	Time (min)
New York (JFK)	San Francisco (SFO)	87.4	6.7	64	4,930	381
New York (JFK)	Los Angeles (LAX)	54.2	4.6	81	3,847	329
Boston (BOS)	San Francisco (SFO)	76.7	7.9	36	2,471	256
Boston (BOS)	Los Angeles (LAX)	96.8	6.1	33	2,444	154
Fort Lauderdale (FLL)	Los Angeles (LAX)	40.8	4.8	39	1,456	172
Chicago (ORD)	San Francisco (SFO)	47.1	3.6	35	1,382	106
Washington (IAD)	San Francisco	42.9	6.4	28	1,086	162
Total Annual Benefit (Wind Use Case)				851*	24,700	2,290
Total Annual Benefit (Wind, Convective Wx, and expired TMI)				851*	$\boxed{27,610}$	2,544

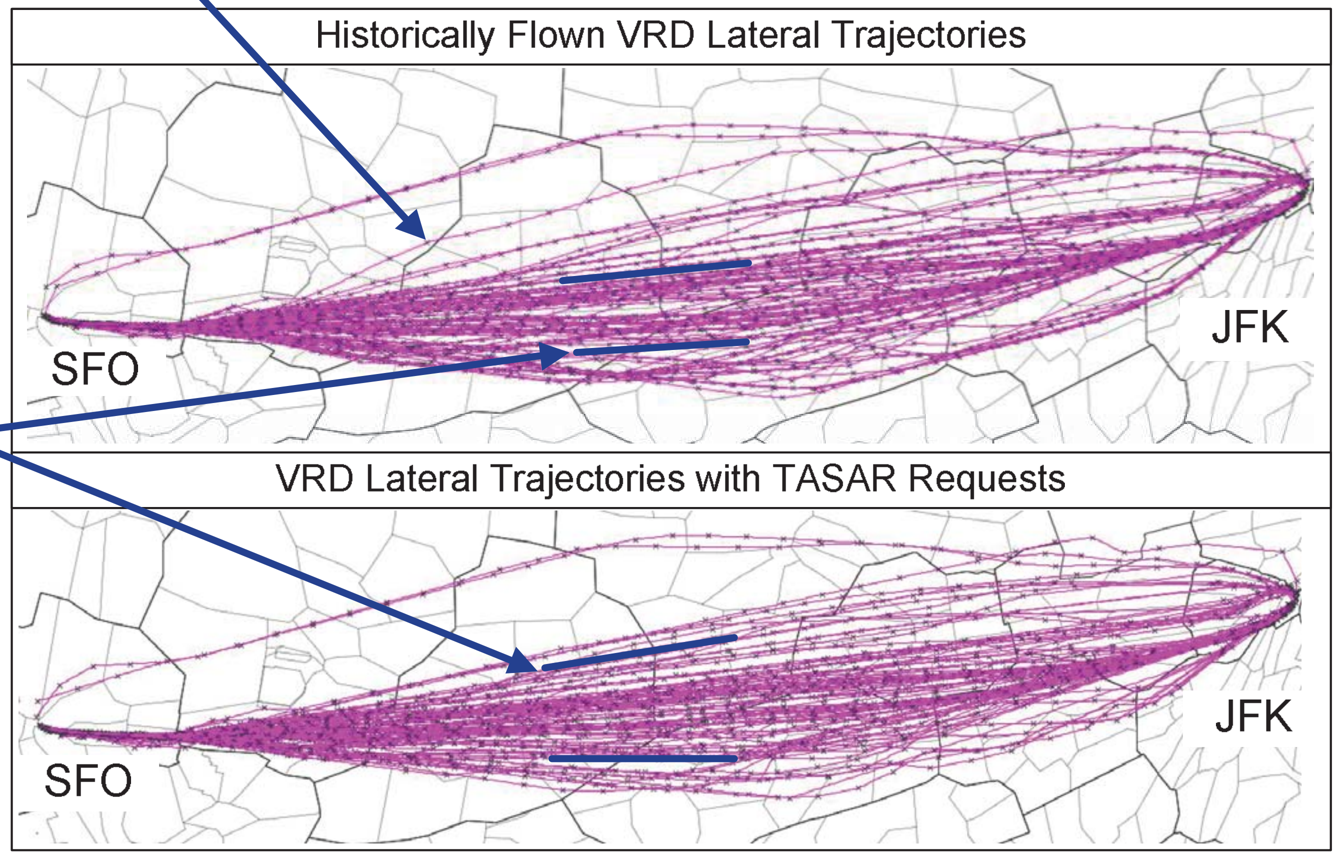
TASAR fuel savings is at least 27,000 gal per A320 per year

* Note: Not all airport pairs shown.

Trajectories between JFK and SFO (highest annual A320 TASAR fuel benefit)

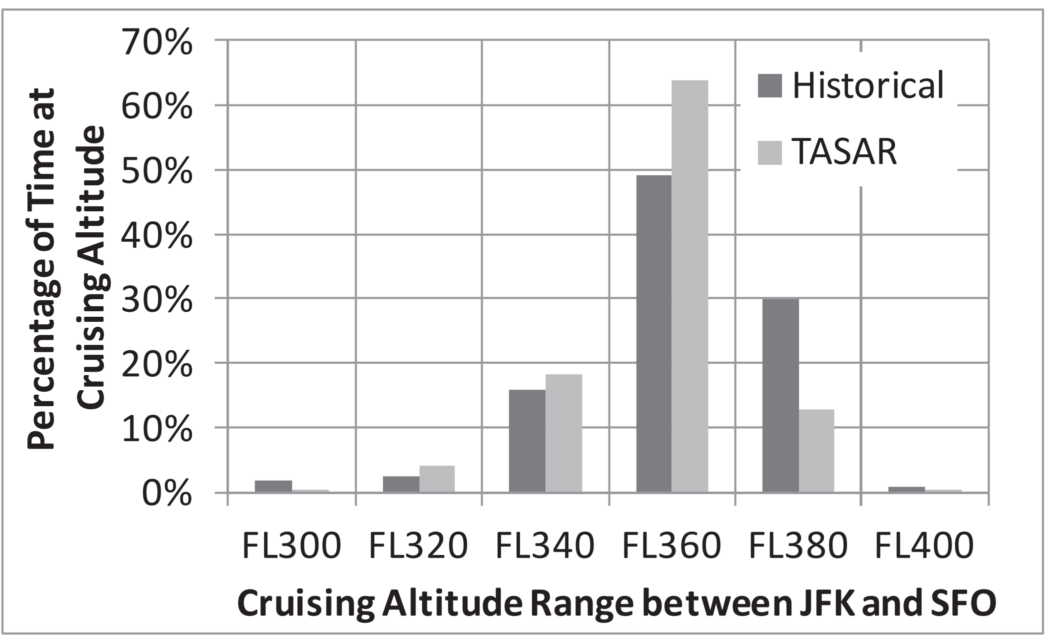
Expired TMI

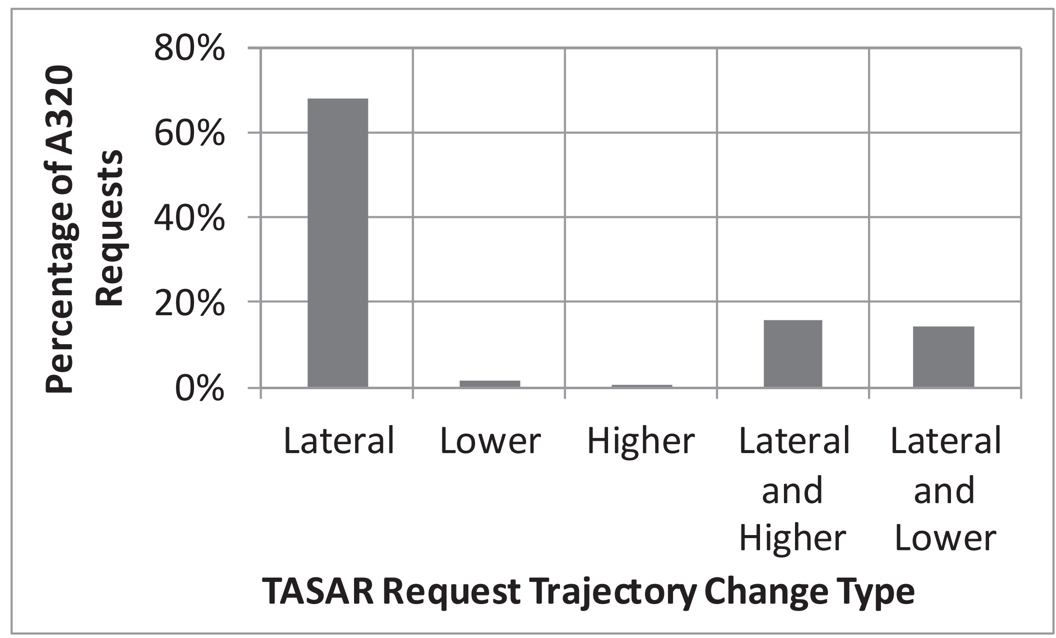
TASAR requests not simple directs. Larger spread result of TASAR taking advantage of changing atmospheric conditions and ATC restrictions.



Altitudes between JFK and SFO (highest annual A320 TASAR fuel benefit)

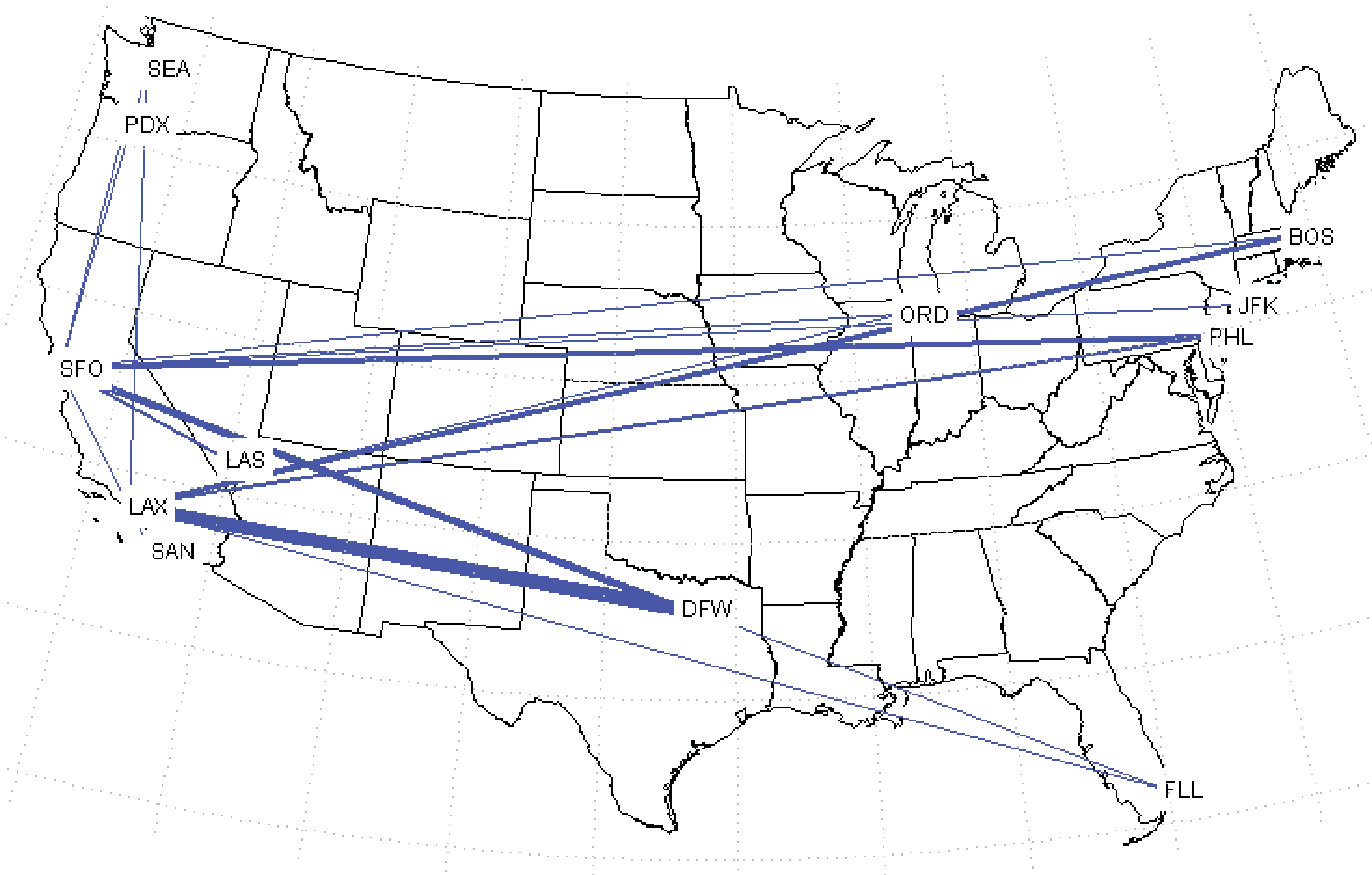
- **On average TASAR requests result in aircraft cruising at lower altitudes between JFK and SFO**
- **Pure altitude changes are least frequent TASAR solution**
  - *TASAR requests generally lateral or combination lateral and vertical*





A319 benefits by airport pair

- Line thickness represents relative fuel benefit per aircraft per year between airports
- TASAR is expected to have highest benefit for A319 operations between Dallas-Fort Worth (DFW) and Los Angeles (LAX)
    - *Benefit = (fuel benefit per operation) * (estimated annual operations between airport pair per aircraft)*



Airport pairs with highest expected annual fuel benefits for A319 when using TASAR

Airport 1	Airport 2	Per Operation Benefit		Annual Benefit		
		Fuel (gal)	Time (min)	Ops per A319	Fuel (gal)	Time (min)
Dallas (DFW)	Los Angeles (LAX)	47.1	2.2	129	5,121	234
Dallas (DFW)	San Francisco (SFO)	50.0	2.4	70	2,920	142
Las Vegas (LAS)	San Francisco (SFO)	12.4	1.0	181	2,250	181
Los Angeles (LAX)	Philadelphia (PHL)	55.7	2.9	42	1,937	102
Boston (BOS)	Los Angeles (LAX)	96.8	6.1	22	1,629	103
Los Angeles (LAX)	Seattle (SEA)	28.7	1.3	52	1,351	62
Chicago (ORD)	San Francisco (SFO)	47.1	3.6	30	1,185	90
Total Annual Benefit (Wind Use Case)				1048*	22,789	2,458
Total Annual Benefit (Wind, Convective Wx, and expired TMI)				1048*	$\boxed{25,614}$	2,684

TASAR fuel savings is at least 25,000 gal per A319 per year

* Note: Not all airport pairs shown.

Fuel and Time Savings Summary

Aircraft Type	Annual TASAR Fuel Benefit	Annual TASAR Time Benefit	Airport Pair with Highest TASAR Benefit
A320	27,000 gallons/aircraft	2,500 min/aircraft	JFK – SFO
A319	25,000 gallons/aircraft	2,600 min/aircraft	DFW – LAX
All aircraft	1,411,000 gallons*	133,500 min*	DFW – SFO

*** Assumes 43 A320s and 10 A319s.**

Estimated Cost Savings Summary

Aircraft Type	Fuel Cost/Gallon	Maintenance Cost/min (2013)*	Depreciation Cost/Min (2013)*
A320	$3.03	$5.51	$0.54
A319	$3.03	$5.68	$0.54
Total Cost Savings by Category	$4,275,000/year**	$740,000/year**	$72,000/year**
Total Cost Savings for all Categories	$5,087,000/year**		

* Obtained from BTS Form 41 data

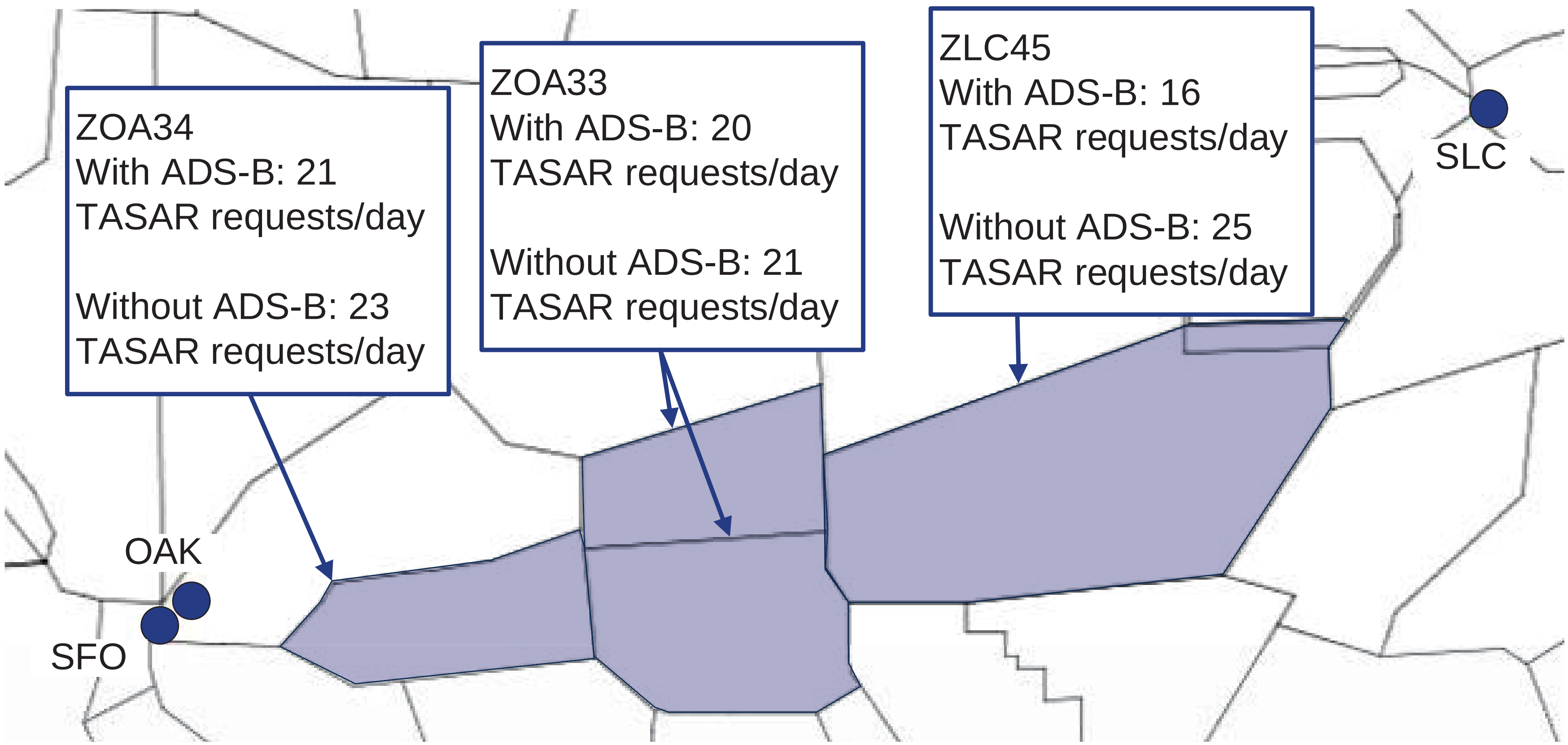
** Applies fuel and time savings from previous slide.

ATC Impacts

- **Average of 3.9 requests per flight**
  - ***Without ADS-B IN – 23% of requests rejected due to conflicts or other reasons***
  - ***With ADS-B IN – 8% of requests rejected due to conflicts or other reasons***
  - ***Request rejections do not significantly impact benefits – aircrew waits until next sector then makes same or similar request***

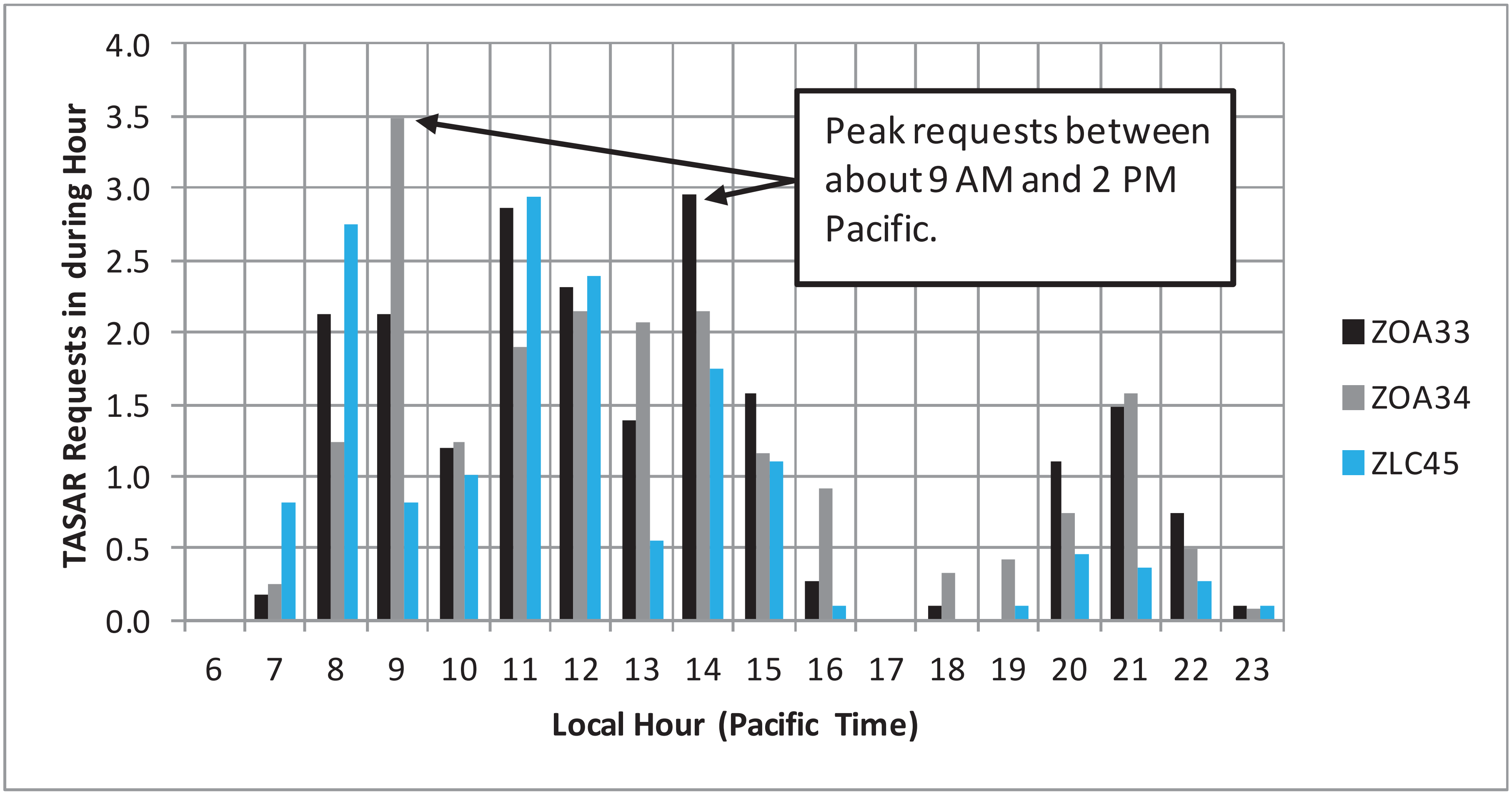
ATC Impacts

- **Virgin America requests spread across country**
- **Top three Virgin America TASAR request sectors**
  - *High altitude ZOA/ZLC sectors*
  - *Experienced 10% of total TASAR requests*



ATC Impacts

- **Peak Virgin America TASAR requests are about 2 to 4 requests per hour per sector**
- **Could be managed through dispatcher coordination or other procedure**



Future Work

- **Second TASAR flight trial planned for 2015**
  - ***Generating method to validate TAP computed outcomes is an objective of the flight trial***
  - ***Controller observations to better understand TASAR request acceptability***
- **Expected TASAR to be placed on a Virgin America revenue flight after flight trial**
- **Validation method, controller observations, and Virgin America revenue flight data could be used to refine benefits estimated by simulation**